RESEARCH HIGHLIGHT

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REDUCTION OF AIRBORNE PARTICLES IN HOUSES WITH OCCUPANTS HAVING RESPIRATORY AILMENTS

INTRODUCTION

An expanding body of public health research has identified airborne particles as a cause of respiratory ailments. A number of studies have examined the concentration of fine particles in indoor air and the incidence of respiratory complications. In these studies, the average concentration over the period of one or more days was considered. Little attention has been paid, however, to variation in concentration over shorter time scales, such as over the course of a day. This can be investigated by sampling the air at multiple indoor locations and counting the particles in the sampled air streams using a laser counter. This approach, already used in previous CMHC studies, facilitates an understanding of the fluctuation in indoor air particle concentrations.

PROJECT OBJECTIVE

The ultimate goal of this effort is to determine how the concentration of indoor airborne particles can be reduced so as to improve air quality for occupants with respiratory ailments. This study aimed to document, over periods of several days, the evolution of airborne particle concentrations in five houses, to determine the factors influencing the evolution of these concentrations, including activities such as cleaning or carpet removal, and to evaluate the efficacy of measures normally recommended for the reduction of airborne particles.

PROCEDURE

Measurement of Particle Concentrations

Five houses, differing in age, construction, and heating system, were chosen; each had at least one occupant suffering from a chronic respiratory ailment (such as asthma or chronic obstructive pulmonary disease). Particle concentrations were measured with a laser counter calibrated to detect particles ranging in size from 0.3 microns to 0.5, 1, 5, or 10 microns. The number of particles for a fixed sampling period and rate was converted to units of $\mu g / m^3$. As per the adopted naming convention, PM 1 is ascribed to the mass of particles in the size range of 0.3 to 1 microns contained in a cubic meter of air, and PM 10 the concentration of particles in the range of 0.3 to 10 microns. A range of household activities and air quality corrective measures were carried out, typically separated by an elapsed period of two to four days. Measures were taken during summertime and during the heating season, when windows and doors were kept closed. The laser particle detector was connected to a sampling rig that permitted the analysis of the air from five different locations: one outside, at 1 m from the building, and four inside the house, of which one was in the basement and another in the bedroom of the occupant afflicted with the respiratory ailment.

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Validity and Limitations of Measurements

The primary test equipment failed part way through this study; a second testing apparatus, more compact and easy-to-use than the primary equipment, but utilizing discrete rather than continuous sampling, permitted the completion of the study. The measurements of the secondary apparatus were validated for particle sizes in the range of 0.5 to 5 microns. The measurements taken in this study can be used with confidence, especially in analysis involving relative variation in concentration levels, considering that:

- The PM 10 exterior measurements and the exterior air quality index, as evaluated by the Montréal air quality measurement network, was verified to be strongly correlated on a number of days.
- There was a strong correlation between the measurements taken by the two test apparatus, despite differences in equipment and utilization, and given that the optical counters are accurate only to within 20 per cent.
- When the same house was tested twice, first with the primary apparatus and then, following an elapsed period of several months, with the secondary apparatus, similar particle levels and air quality problems were observed in both cases.

The houses in this study were occupied during monitoring, imposing certain limitations on the conclusions that can be drawn due to the marked influence of occupant activity on particle concentrations. The nature of the meal prepared in the house on a given day, or even the unusually forceful drawing of a curtain, could cause a peak in particulate emission and exert the same level of influence on the average concentration for the day as, for instance, the configuration of the ventilation or filtration system. The impact of changes in the ventilation or central filtration system configuration could be unambiguously identified only in an unoccupied house.

Finally, it was noticed that the measurements of one of the laser detectors were distorted by conditions of unusually high relative humidity in the outside air due to, haze-forming conditions and in the inside air (resulting from cooking or showering). This was manifested by a strong increase in the measured values. This was observed in the outside air measurements on a single day only, for which data were consequently disregarded.

Presentation and interpretation of measurements

For every 24-hour measuring period, measurements taken every 10 to 20 minutes were plotted as a time series and the average for each measurement location was calculated for the same period. The following figure is an example of the results from a house with a ventilation heat recovery unit, employing a HEPA filter, providing fresh air to the basement and exhausting air from upstairs landing, with the bedroom doors closed. This example illustrates the possibilities of using laser detectors with sampling at multiple locations in order to identify household airborne particle problems, and potential solutions for those problems.

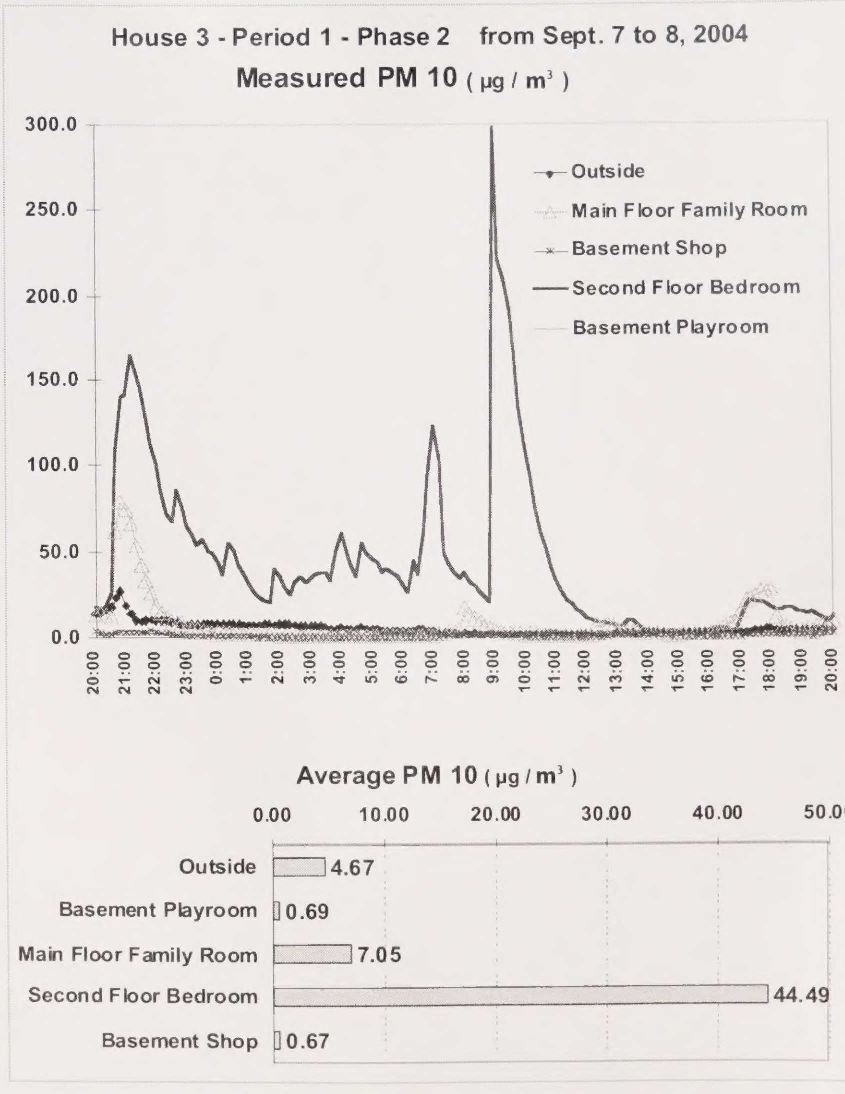

Figure 1: House 3 - Period 1 - Phase 2 Bedroom door closed
HRV with HEPA filter providing fresh air to basement. Inside air exhausted from upstairs landing.

Figure 1 readily reveals the situation in this house:

- The ventilation heat recovery unit with HEPA filter is capable of purifying the air to good effect in the rooms to which it supplies fresh air directly, as evidenced by particle concentrations approximately one-tenth those of the exterior air and one-tenth the average for the entire house. The utility of purifying the air in these little occupied rooms is questionable, however.
- The bedroom, with its door closed, benefits neither from the supply of filtered air nor from the removal of contaminated air via a single exhaust vent located on the same floor level.
- The elevated night time concentrations of airborne particles in the children's bedroom, ten times higher than in the exterior air, points to the bedding as the source of emissions. Bedtime, about 21:30, is followed by a period of moderately high concentrations punctuated by peaks, attributable to the sleeping child's movements; the child rises around 6:30. This hypothesis is tested and confirmed by the shaking of the pillow and duvet, both of goose down, giving rise to the peak at 9:00 on the morning of September 8.
- Household activity peaks around 8:00, 13:00 and 17:00, as reflected in the concentration levels of the main floor, where the kitchen and family room are located.
- Outside periods of peak emissions, particle concentrations tend toward levels below that of the exterior air.

These types of observations guided this study in its investigation of measures aimed at reducing household particle concentration levels. Similarly, these types of observations underpin the generalizations and conclusions of the project. It must be noted that the interpretation of these observations has emphasized the relative, rather than absolute, concentration levels, and particularly the levels relative to the exterior air concentration.

RESEARCH RESULTS

Four of the houses studied here were between 10 and 30 years old. One was a townhouse with electric forced air central heating; two houses (one bungalow + one two-storey) had forced air central heating utilizing both electricity and oil; and one was a two-storey house with electric baseboard heaters. A fifth dwelling was the upper storey of a duplex more than 50 years old, located in downtown Montréal, and with electric baseboard heating.

The ratio of interior to exterior PM1 and PM10 readings showed significant variation from one day to the next and, more significantly, between the different houses. In all houses, in both indoor and outdoor measurements, the PM1 and PM10 measurements are nearly perfectly correlated: a change in PM10 was echoed by a virtually identical, simultaneous change in PM1.

The strongest increases in household particle levels were caused by the activities of the occupants, notably cooking and handling of bedding, curtains, and certain upholstered furniture. Houses with little clutter and a majority of surfaces being hard or smooth appeared to have less pronounced particle concentration peaks, outside of cooking times, if cleaned regularly (for example, more than once a week, with bedding and carpets cleaned several times a year). In all houses, periods of low occupant activity, such as night or when occupants were absent, were characterized by interior particle concentrations tending to stabilize at levels below that of the outside air.

Filtration systems can effectively lower particle concentration levels, but only during periods of little occupant activity, such as when occupants are sleeping, and only in those rooms directly furnished with the filtered air. The monitored data did not show particle concentrations being strongly influenced by carpet removal or housekeeping over a two-day period following the event.

RESEARCH CONCLUSIONS

The variation in PM1 and PM10 in household air is considerable over the course of a day. The measures of the particle level of these two categories of size are correlated, their evolution following the same profile in time. Over a day, several pronounced peaks in particle concentration, sometimes attaining levels several orders of magnitude greater than the concentrations levels in the house during periods of minimal activity, are generally observed. Filtration systems are unable to respond instantly to such peaks. The peaks usually stem from occupant activities.

- A house can be considered a reservoir of particles, ready to be launched into airborne suspension by occupant activity, regardless of exterior particle concentrations.
- The mean household particle concentration and the outside air particle concentration are correlated, as observed on days when there is little occupant activity or in houses relatively clean of "stored" particles. The correlation is negligible or absent during times of high occupant activity or in houses with significant stored sources of particles.
- During periods of occupant activity, interior airborne particle concentrations will rise, in both the 1 micron and 10 micron range of particle sizes, regardless of the capacity or effectiveness of an air filtration system.
- A filtration system can be effective at reducing average daily airborne particle concentrations during periods of low or no occupant activity, notably during the night.
- A filtration system effectively reduces airborne particle concentration levels only in those rooms it supplies directly, suggesting that the filter, or the vent supplying filtered air, should be located, for example, in occupied bedrooms.

Given the small number of houses studied in this project, it was not possible to determine a direct link between better indoor air quality and improved occupant health.

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Housing Research at CMHC

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